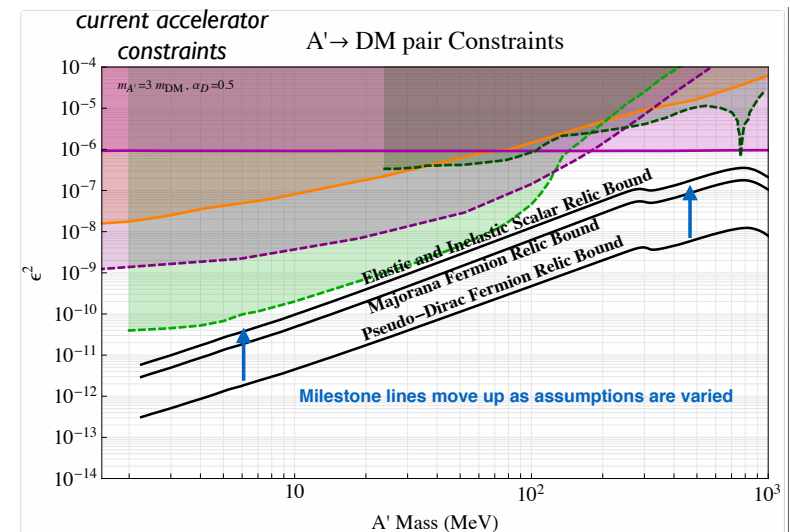# Probing the thermal relic target with accelerator-based experiments

Very fruitful workshop!

Over 20 talk in WG3 parallel session, including current results, new theoretical ideas, facilities and new proposals as well as interesting discussions.
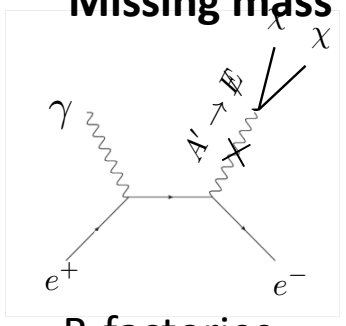
New proposals aimed at definitely probing the thermal relic target in the MeV-GeV range with different approaches.

Most of these proposals are based on proven technology / techniques, and could be deployed in the near future (if not already in construction)
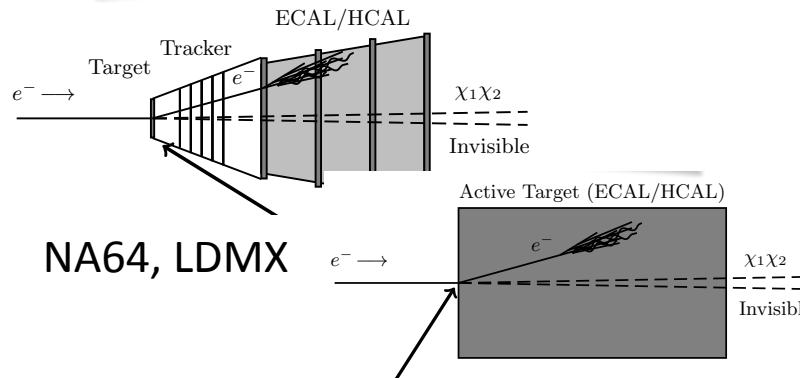
Probing the thermal relic target with accelerator-based experiments
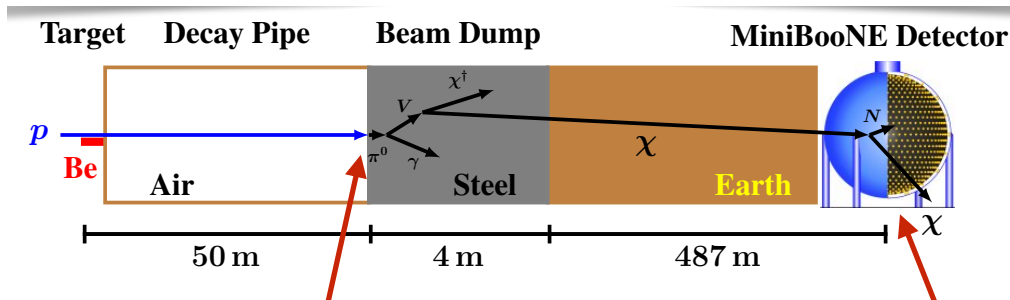
Missing mass

B-factories
PDME,MMAPS,
DarkLight

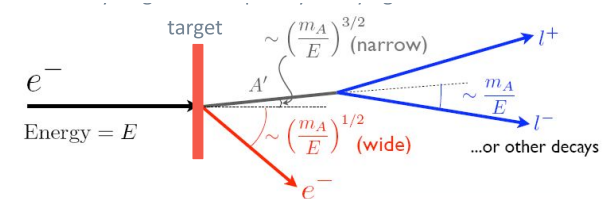## Missing energy / missing momentum

NA64, LDMX

Proton / electron beam dump

MiniBooNE, SBN,COHERENT, SHiP, BDX, BDX-drift,…

Searches for the mediator

HPS, SeaQuest, Magix

Highlights from the missing mass approach

BABAR / Belle II (C. Hearty)

BaBar single photon search

- Optimized for and interpreted in terms of a dark photon A′ decaying invisibly.

$$E_\gamma^* = \frac{\sqrt{s}}{2} - \frac{m_{A'}^2}{2\sqrt{s}}$$

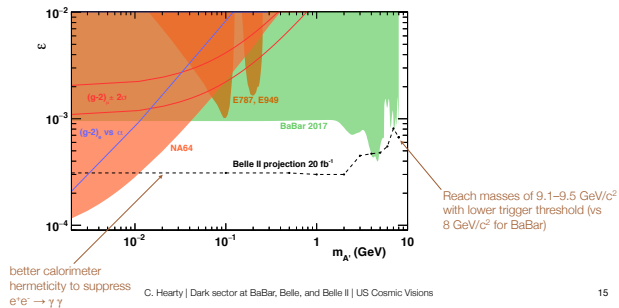- We assume on-shell A′ ($m_\chi < m_{A'}/2$), so signal is a monoenergetic photon.

  - analysis is otherwise not sensitive to m_χ or to the coupling of the χ to the A′.

Projected Belle II exclusion region, 20 fb⁻¹

- Assumes we can quantitatively predict background levels.
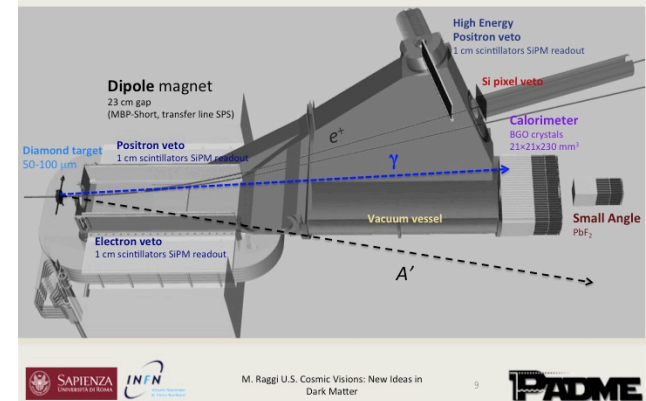 - photon efficiency over barrel/endcap gaps.

Reach masses of 9.1–9.5 GeV/c² with lower trigger threshold (vs 8 GeV/c² for BaBar)

better calorimeter hermeticity to suppress $e^+e^- \to \gamma\gamma$

PADME (M. Raggi)

PADME experiment setup

High Energy Positron veto
1 cm scintillators SiPM readout

Si pixel veto

Dipole magnet
23 cm gap
(MBP-Short, transfer line SPS)

Calorimeter
BGO crystals
21×21×230 mm³

Diamond target
50-100 μm

Positron veto
1 cm scintillators SiPM readout

Vacuum vessel

Small Angle
PbF₂

Electron veto
1 cm scintillators SiPM readout

A′

What if PADME comes to US?
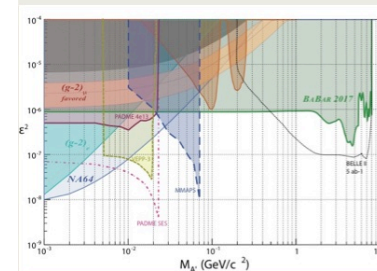
- Main limitation on PADME sensitivity comes from very small duty cycle of DAFNE Linac (2E-6 – 1E-5)
  - 50Hz x 40-250ns bunches
- Beam energy limits PADME mass reach
  - 550MeV limits $M_{A'}$ < 23.7MeV

- PADME coming to Cornell can profit of:
  - x10000 higher luminosity
  - x12 Higher energy $M_{A'}$ < 78 MeV
- PADME can offer to Cornell:
  - High resolution BGO crystal Ecal
  - Spectrometer magnet and veto detectors

PADME to Cornell will be a few M$ scale project (detector ready by the end of 2017!)
With a time scale of few years (2020-2021)
With an interesting physics reach including A′, ALPs
Will setup a very interesting international collaboration from both sides of Atlantic

Highlights from the missing mass approach

MMAPS (J. Alexander)
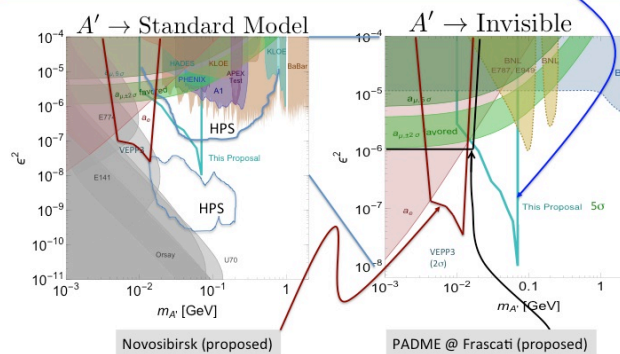
DarkLight (M. Kohl)

Fully developed concepts, ready to be build or in construction

Highlights from the beam dump approach

Slides from Natalia

Highlights from the missing energy / momentum approach

D. Banerjee

NA64: Setup

Key Features of the setup:
- High energy beam to trigger the reaction: 100 GeV e- beam from the CERN SPS.
- Max intensity ~ 5 x 10^6 e-/ spill.
- Typically 2 spills/min
- Main impurities of H4 beam: $\pi-$, low energy e– (~1%) $\mu-$ and K– (≤0.1%)

October 2016 run and prospects

Projected Sensitivity

- October 2016 run :
  - Good performance at 5x10^6 e-/spill
  - 4x10^{10} eot collected.
  - Data analysis in progress.

- 2017 run
  - Improved e- tagging: tracker+SRD
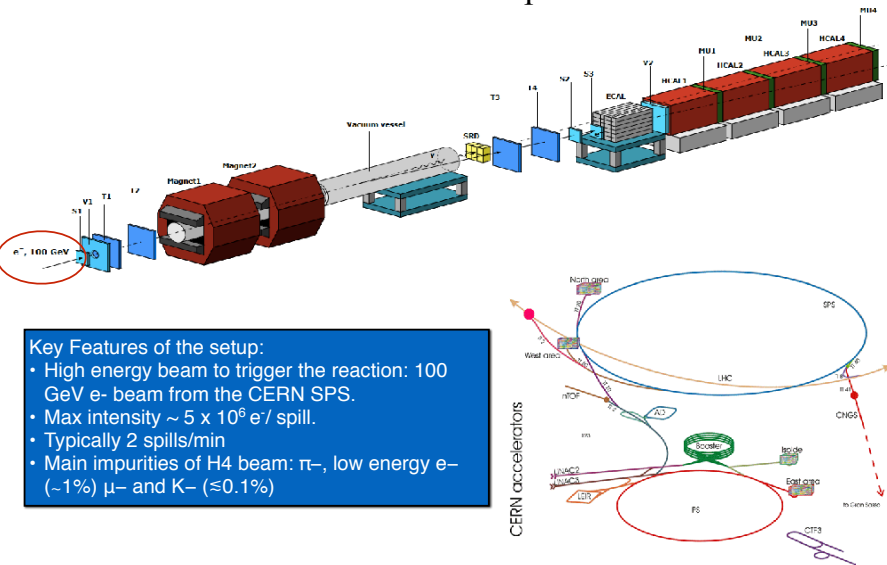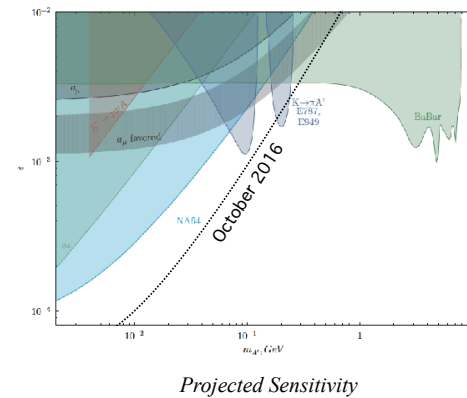 - Tests at intensity (7–8)x10^6 e-/spill
  - Goal (2–3)x10^{11} eot.

The run 2017 :
- *Plan to collect up to few 10^{11} electrons on target for the invisible channel and cover significant area of the A' parameter space.*
- *Upgrades to the tracking system as well as to the synchrotron radiation detectors are foreseen.*
- *We also intend to switch to visible mode to collect few 10^{10} eot (> 1 week) to address the Be8 decay anomaly which could be explained by a 17 MeV boson.*

Highlights from the missing energy / momentum approach
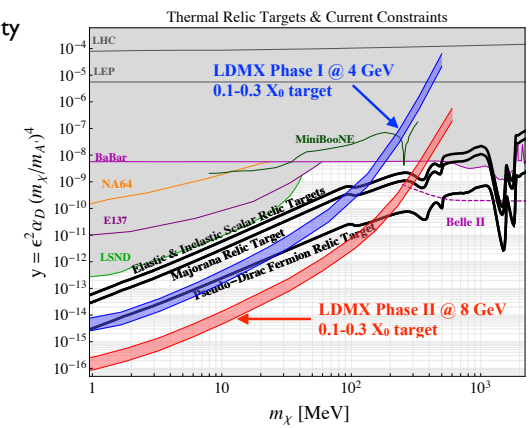
T. Nelson

LDMX Phase I Detector Concept

LDMX

18D36 Dipole
36"
$\vec{B}$
vacuum chamber
4 GeV e⁻
ECal
HCal
tagging tracker
recoil tracker
target
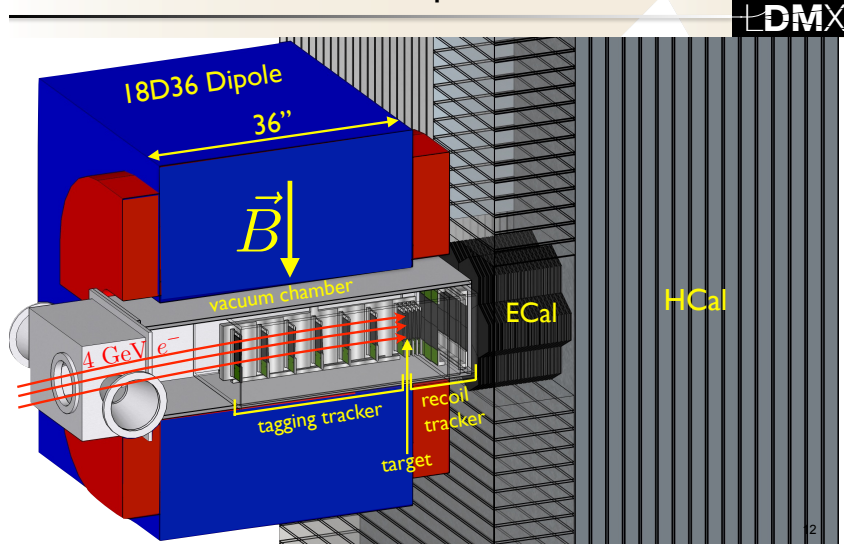
Summary and Outlook

LDMX

Accelerator-based DM searches have unique sensitivity in the MeV-GeV range.

Missing Energy/Momentum experiments provide best sensitivity per luminosity.

LDMX can robustly reach all thermal targets over most of the MeV-GeV range.

LDMX can complete this program within the next decade at reasonable cost.

Thermal Relic Targets & Current Constraints

LDMX Phase I @ 4 GeV
0.1-0.3 X₀ target

LDMX Phase II @ 8 GeV
0.1-0.3 X₀ target

$y = \epsilon^2 \alpha_D (m_\chi/m_{A'})^4$
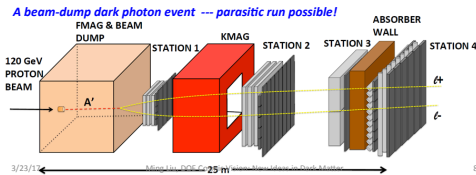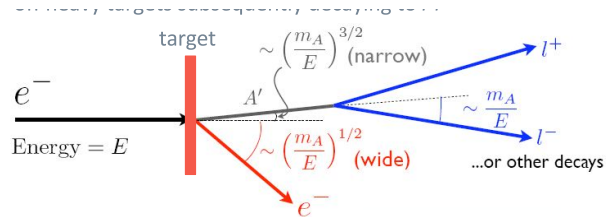
m_χ [MeV]

30

LDMX can robustly reach all thermal targets over most of the MeV-GeV range

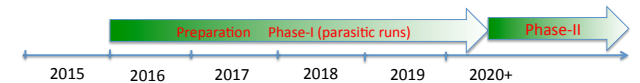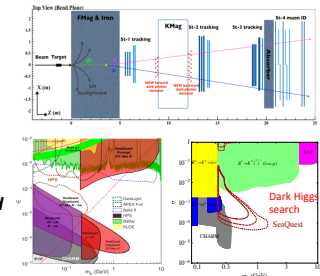LDMX can complete this program within the next decade at reasonable cost.

Highlights from the mediator search

$$\sim \left(\frac{m_A}{E}\right)^{3/2} \text{(narrow)}$$

$$\sim \frac{m_A}{E}$$

$$\sim \left(\frac{m_A}{E}\right)^{1/2} \text{(wide)}$$

...or other decays

target

e^-

Energy = E

A'

l^+

l^-

e^-

A beam-dump dark photon event --- parasitic run possible!

SeaQuest (M. Liu)

Summary and Outlook

- **Phase-I**
  - *Great discovery potential!*
  - *A new vertex trigger & DAQ++*
  - *Early parasitic data taking 2017-2020+*
  - *POT 1.4 x10^{18} or more*

- **Phase-II**
  - *Possible detector upgrade later, add electron and hadron capability*
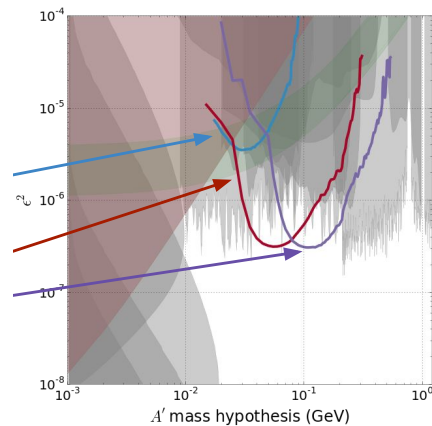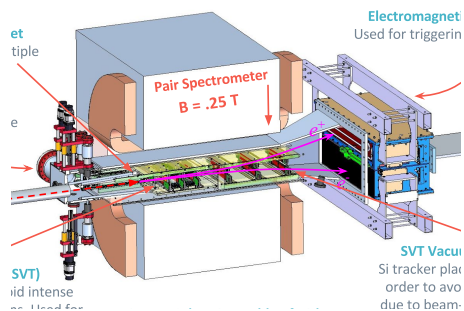 - *A new dedicated dark matter program at Intensity Frontier!*

Dark Higgs search
SeaQuest

Preparation   Phase-I (parasitic runs)   Phase-II

2015   2016   2017   2018   2019   2020+

3/23/17   Ming Liu, DOE Cosmic Vision: New Ideas in Dark Matter   21

The HPS Apparatus

Electromagnet
Used for triggering

Pair Spectrometer
B = .25 T

SVT Vacuum
Si tracker placed in order to avoid due to beam

(SVT)
id intense
s. Used for

Enabling the science

Facilities: DASEL

Enabling the science

Facilities: Fermilab

Enabling the science

Facilities: JLab

Summary table of proposals

Name	type	Data taking	Cost

Summary plots and conclusion